

Attention in sense of touch

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Attention in somatosensation

In everyday life the human brain is confronted with an enormous amount of sensory input at any given moment. To guarantee coherent and adaptive behaviour, selective attention is needed to focus the limited processing resources on the relevant part of the available information while ignoring the rest [1, 2]. This chapter provides an overview on some topics of current research in attention and the sense of touch. We will mainly focus on studies using mechanical stimuli rather than electrical stimulation. The physical characteristics of electrical stimuli (sharp and short duration of only a fraction of a millisecond) makes them closer to pain stimuli and, thus, suboptimal to mimic the complex interactions between different mechanoreceptors of the glabrous skin [3–5]. In contrast, mechanical stimuli have not such a sharp onset (mostly they are delivered in form of a sinusoid, see below) and make contact with the skin for much longer. Therefore, mechanical stimuli seem to mimic everyday experience of touch more closely as opposed to electrical stimuli. A second aim of this chapter is to discuss possible neuronal mechanisms that explain how to-be-attended tactile stimuli are processed preferentially in the brain.

Research on attention has a long history and definitions of attention varied from time to time. In 1890, William James [6] wrote: “*my experience is what I agree to attend to*”. Along the same line, John Driver defined attention as “*a generic term for those mechanisms, which lead our experience to be dominated by one thing rather than another*” [7]. The main behavioural signature of atten-

tion is the improved accuracy in analysing and speeded detection or discrimination of attended stimuli.

But what makes somatosensation so different from other senses to look exclusively into the impact of attention onto that sensory system? Hsiao and Vega-Bermudez [8] nicely illustrated that point with the following example: “*if you switch your focus of attention to your foot, you immediately become conscious of sensations arising from receptors in your foot that were non-existent a moment earlier. This simple observation demonstrates the power of selective attention*”. Based on that illustration the authors concluded that attention in somatosensation plays its role in the selection of specific sensory inputs at certain body locations. While this is not particularly different from other modalities when we focus on spatial accounts of attention, Forster and Eimer [9], among others, discussed an important difference compared to other sensory modalities. Contrary to vision for instance, in touch one interacts with proximal stimuli impinging on our body surface. In other words, while visual and auditory stimuli might be miles away from our body, somatosensory stimuli are not. They have an immediate impact onto our body surface, which makes somatosensory stimuli very different from auditory or visual ones. A further difference might lay in the fact that to a great extent primary somatosensory areas also appear to represent non-spatial attributes of tactile events [10, 11]. This feature not only enables a fast analysis, which is ecologically quite useful, it also makes non-spatial attentional selection accessible at a very early level of stimulus processing.

Somatosensory attention and transient stimuli

Most of the studies conducted so far focused on spatial somatosensory attention. Within this framework, attention is focused on a particular body location and stimuli presented at that location are processed faster compared to stimuli presented to any other body location. Only a few studies, which will be reported below, investigated feature-based attention. In feature-based attention subjects are required to discriminate between different features, such as texture or stimulation frequency, rather than a certain body location alone. Of course, spatial and feature-based attention in many cases is mixed, because to discriminate between different features, stimuli have to be presented at a certain body location. The crucial point here is the task subjects have to fulfil.

The effect of spatial attention on early perceptual processes in the visual [12] and auditory [13] modality has been illustrated by an amplitude modulation of early components of the respective sensory-specific event related potential (ERP). In somatosensation, a number of studies in monkeys and humans have also shown that the neuronal response to an attended tactile stimulus is enhanced compared to when this stimulus is unattended (for a further review see [14]). Single-unit recordings in monkeys showed an increase in firing rate to transient tactile stimuli in primary somatosensory cortex (SI) [15]. Imaging techniques, such as positron emission tomography (PET) and functional magnetic resonance imaging (fMRI) found attentional modulation of the blood oxygen level dependent (BOLD) response in primary and in secondary somatosensory cortex (SII) [14, 16–19].

In human non-invasive electrophysiological studies, transient tactile pulses elicit the somatosensory evoked potential (SEP) or the magnetic counterpart, the somatosensory evoked magnetic field (SEF). The SEP consists of the components P50, N70, P100, N140 and a positive late component [20–23]. Figure 1 depicts examples of SEPs and the attentional modulation thereof.

Mima and colleagues [24] reported of early SEF components with a latency of 38 and 68 ms.

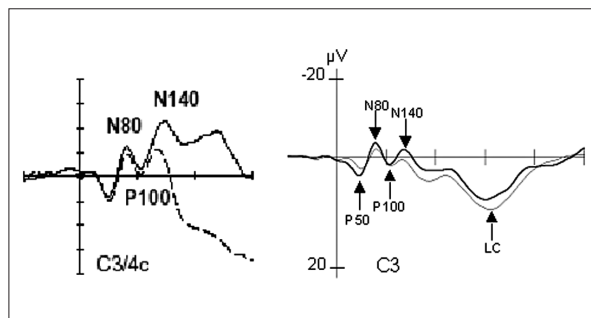


FIGURE 1. EXAMPLES OF SOMATOSENSORY EVOKED POTENTIALS (SEPs) TO TRANSIENT STIMULI

The SEP consists of typical positive and negative going peaks, namely the P50, N80, P100, N140 and late component (LC). Numbers refer to the approximate peak latency after stimulus onset while P and N refer to a positive or negative going peak, respectively. Attending to a tactile stimulus resulted in marked increases of the N140 component and less positive going LC. Left panel is take from [9] and right panel from [23], with friendly permission.

These early responses were modulated with attention and had their sources in SI. However, they also reported an attentional modulation of later SEFs (125 and 138 ms), which had their sources in SII. These very early effects of spatial attention in SI might, however, be due to the nature of electrical median nerve stimulation used in that study (see remark above). With mechanical stimulation results are mixed, since early as well as late spatial attentional modulations of SEP components were reported. Eimer and colleagues [25] showed effects as early as overlapping with the N80 component. On the other hand attentional modulations no earlier than at the level of P100, and N140 [9, 23] have also been described (see Fig. 1). Together, these results suggest that the stage at which spatial attention alters the neural responses to transient stimuli is not a hard-wired mechanism but might be influenced by a number of variables.

One such variable might be the level to what extend stimuli have to be processed in order to perform a particular task. In humans [9, 25] as